Drinking water consumption patterns in Sweden

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ABSTRACT

Estimates on drinking water consumption are necessary in risk assessments on microbial hazards in drinking water. Large differences in consumption habits between countries have been reported. In order to establish estimates for the Swedish population, water consumption data from a waterborne outbreak investigation (157 people), a small water consumption study (75 people) and a large study on health and environmental factors (10,957 people) were analysed. A lognormal distribution for the daily direct/cold water intake in litres with $\mu = -0.299$ and $\sigma = 0.570$ was fitted to the quantitative data, representing the general population. The average daily consumption of tap water as plain drinking water and as heated tap water, e.g. in coffee and tea, was 0.86 ± 0.48 l and 0.94 ± 0.69 l, respectively. Women consumed more cold tap water than did men, while men appeared to have a higher consumption of heated tap water. Cold tap water intake was highest in the oldest age group, ($\geq$70 years). The consumption of bottled water was very low (mean 0.06 l/d) when compared to other countries.

Key words | demographic variables, drinking water consumption, probability distribution, risk assessment, tap water, water intake

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INTRODUCTION

Quantitative microbial risk assessment (QMRA) is increasingly being used for management purposes in the water industry, for example, in order to determine if the treatment is sufficient to prevent illness in the population and how to most efficiently avoid or control drinking water hazards. In order to determine the dose of pathogens potentially reaching the consumers, estimates on the amount of tap water ingested per day are needed. The standard quantities most often used are 2 litres per day for adults and 1 litre per day for children and have been adopted by for example the United States Environmental Protection Agency (USEPA) and the World Health Organisation (WHO). These estimates originate from assumptions published by the Safe Drinking Water Committee of the National Academy of Sciences in 1977 (NAS 1977) and have been shown to be in agreement with the 88th percentile of the per capita water ingestion rates in the USA (USEPA 2000).

Although point estimates can be applied in QMRA it is preferable to use statistical distributions of parameters in order to account for variability and uncertainty in the data. Roseberry & Burmaster (1992) fitted lognormal distributions to the data from an American food consumption survey from 1977–1978. Later, Burmaster (1998) also fitted distributions for water intake among pregnant and lactating women based on the same survey. In both these studies distributions are presented for tap water intake and total water intake, respectively, however no differentiation is made between tap water consumed directly and heated tap water. While this is sufficient in chemical risk assessment when estimating the exposure to different chemical substances in water, such a differentiation is essential in microbial risk assessment since only the unboiled water constitutes a risk. The only paper presenting a distribution of the direct, or cold, tap water intake is that by Teunis & Havelaar (1999) based on a Dutch survey.

There appear to be large differences in tap water consumption between countries. While the daily median intake of cold tap water was 0.153 l in the Dutch survey

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(Teunis & Havelaar 1999) the corresponding mean intake during late spring in a French study was 0.90 l (Gofti-Laroche *et al.* 2001). Differences in tap water consumption have also been reported regarding demographic variables such as age, sex and geographic area. Forhammar *et al.* (1986) collated data from a few Swedish studies on tap water consumption and concluded that 15-month-old infants had the highest consumption of tap water in relation to their body weight and that lactating women have the highest daily intake of tap water. Similar results are presented by the USEPA (2000).

The aim of this study was twofold; firstly to make a quantitative estimation of the drinking water consumption in Sweden, and secondly to evaluate potential differences in demographic variables that could have an impact on the water intake. Separation of the population into subgroups could be justified to account for sensitive groups, such as infants and children or the elderly (Gerba *et al.* 1996). The data used in this study came from three different sources, a national survey of environmental factors and health from 1999, a waterborne outbreak investigation from 2002 and a smaller water consumption study from 2003.

MATERIAL AND METHODS

Water consumption and demography

During 1999 the National Environmental Health Survey (NMHE99) commissioned by the National Board of Health and Welfare was undertaken in Sweden. The purpose of the survey was to investigate the effect of different factors in the living environment on the physical health of the Swedish population (Miljöhälsorapport 2001). The survey was carried out through questionnaires that were sent out randomly to 750 people in each of the 21 counties. Of the 15,496 people who received the questionnaire, 11,233 responded (response rate 73%) with 10,957 answering the questions on daily water intake within the home. The questions on water intake were separated into cold tap water consumed directly as drinking water, tap water prepared into coffee, tea etc. and daily bottled water consumption. Three alternatives were provided: one litre or more, less than one litre, or none, respectively. In order to investigate the impact of demographic variables (also included in the survey) on water intake, statistical analyses were made comparing the intake between subgroups based on sex, age, geographic location (represented by county), city or countryside, income, state of health, and type of tap water. A weight was used for each observation, adjusting for sample losses and to avoid it being skewed, in comparison to the whole Swedish population regarding population density in the different counties, age, sex, marital status, education and income (Miljöhälsorapport 2001). The demographic characteristics of the data set can be found in Table 1.

Quantitative analysis

The NMHE99 survey was complemented with additional data sets for more specific quantifications of daily water intakes. For cold tap water intake, data collected in an investigation of a waterborne outbreak were used. The outbreak occurred in Transtrand, Dalarna County, in February-March 2002 and coincided with a large cross-country ski competition. An estimated 500 people fell ill with a Norwalk-like calicivirus (Carrique-Mas *et al.* 2003). As part of the outbreak investigation a cohort study was performed with questionnaires sent out to all the 605 permanent residents in the area. Other questionnaires were sent to skiers and school children that had been visiting the town but these were not included in the study since they did not include water consumption during a full day. In one of the questions the respondents were asked if they had been drinking tap water at home or elsewhere. Another question was the number of glasses of unboiled tap water (one glass being 200 ml) that the respondents normally consume per day. Of the 387 people who answered the questionnaire (response rate 64%) 157 people gave information on water consumption (Table 1).

Heated tap water consumption and bottled water consumption was based on a study performed within the research programme Sustainable Urban Water Management ('Urban Water') (Berg & Viberg 2003). Questionnaires on water consumption and consumption patterns were sent out randomly to people in the inner city of Gothenburg and the small town of Surahammar with 75 people responding (response rate 63%) (Table 1). The main questions of

Table 1 | Demographic characteristics of the data sets used in the study

Characteristics	National survey[a] n	(%)	Transtrand n	(%)	Urban Water n	(%)
Sex						
Men	5,462	(49.8)	74	(47.1)	36	(48.0)
Women	5,495	(50.2)	79	(50.3)	39	(52.0)
Age group						
0–9	–	–	16	(10.2)	–	–
10–19	–	–	18	(11.5)	–	–
20–29	2,132[b]	(19.5)[b]	12	(7.6)	10	(13.3)
30–39	2,142	(19.6)	21	(13.4)	14	(18.7)
40–49	1,974	(18.0)	17	(10.8)	10	(13.3)
50–59	2,024	(18.5)	21	(13.4)	18	(24.0)
60–69	1,443	(13.2)	26	(16.6)	8	(10.7)
≥ 70	1,241	(11.3)	23	(14.6)	10	(13.3)
City						
Stockholm, Göteborg, Malmö	3,676	(33.5)	–	–	40	(53.3)
Other	7,281	(66.5)	153	(100)	35	(46.7)
Yearly income (EUR)						
0–11,000	2,910	(26.6)	–	–	10[c]	(13.7)[c]
11,000–22,000	4,750	(43.3)	–	–	13[d]	(17.8)[d]
22,000–32,000	2,406	(22.0)	–	–	36	(49.3)
32,000–43,000	544	(5.0)	–	–	14[e]	(19.2)[e]
≥ 43,000	347	(3.2)	–	–		
Tap water source						
Municipal supply	9,215	(84.1)	112	(71.3)	–	–
Private well (dug)	609	(5.6)	28	(18.5)	–	–
Private well (drilled)	852	(7.8)			–	–
Other	–	–	14	(8.9)	–	–

If percentages do not add up to 100% it is due to missing data not shown in the table.
[a]Weighted data.
[b]Also includes 19-year olds.
[c]Less than 16,000 EUR.
[d]16,000 to 22,000 EUR.
[e]32,000 EUR or more.

interest for this study were the amount of heated tap water consumed within and outside the home (either as pure water or as a base for coffee, tea, chocolate, soups etc.) and the amount of bottled water consumed per week (five alternatives were provided: none, 0.5 litre or less, 0.51 to 1.0 litre, 1.01 to 2.0 litres, or 2.01 litres or more).

Statistical analysis

Chi-square tests were performed in order to compare proportions in different groups of the study populations with that of the whole Swedish population (based on data from Statistics Sweden (2003)). The non-parametric test 'Kruskal-Wallis one-way analysis of variance on ranks' was used for analysing the ordinal data on water consumption from the NMHE99 regarding differences in demographic variables. Pairwise comparisons between groups were analysed with Mann-Whitney. Spearman rank correlation was used to identify significant relationships between variables. One-way analysis of variance (one-way ANOVA) was used for analysing differences between sex and age groups in the quantitative data from the Transtrand outbreak and the Urban Water study. The significance level was set at 0.05. The statistical analysis was performed using 'SPSS for Windows' version 11.0 (SPSS Inc., Chicago, USA). Probability density functions were fitted to the data on cold tap water intake from the Transtrand outbreak through maximum likelihood estimation (Devore 2000). Although the collected data were discrete (number of glasses), continuous distributions were used since we believe that this better reflects the actual intake. A similar procedure was used for quantification of the bottled water consumption from the Urban Water study where the ordinal data was transformed into a continuous distribution by calculating the probability of data falling in each of the categories. The mathematical analysis was carried out in Mathematica version 5.0 (Wolfram Research, Champaign, USA).

RESULTS

Direct/cold tap water intake

Water consumption and demography

Out of the 10,957 respondents in the NMHE99 survey 4% answered that they did not drink any cold tap water at home on a daily basis, 54% stated an intake of less than one litre and 42% one litre or more.

There was a statistically significant difference ($P < 0.001$) between the sexes in the amount of tap water consumed as drinking water. Women drank more than men with 47% of the women reporting a daily intake of one litre or more. The corresponding figure for men was 37% (Figure 1a). There was also a significant difference ($P < 0.001$) in cold tap water intake between age groups. People between 40–49 years consumed the least while people in the oldest age group, ≥ 70 years, consumed the most with 50% consuming at least one litre per day (Figure 1b).

People living in any of the three largest cities consumed less than the rest of the Swedish population ($P < 0.001$; Figure 1c). The geographic difference regarding counties was also significant ($P < 0.001$) with a trend of increasing water consumption the further north the county was located.

There was a significant decrease in cold tap water intake with increasing yearly income ($P < 0.001$, correlation coefficient -0.091, Figure 1d).

The respondents were also asked to judge their general health condition compared to other people of their age. There was a significant difference ($P; = 0.001$) in the amount of water consumed depending on health status but no trend in either direction could be observed (Figure 1e). The group of people who regarded themselves to be of very bad health had the highest proportion of non-consumers (11%) as well as the highest percentage of high consumers (≥ 1 l: 52%).

People receiving municipal water consumed slightly more water than those with excavated private wells and significantly ($P; = 0.026$) more than those with drilled private wells (Figure 1f).

Quantitative analysis

The proportion of men and women and of people in different age groups represented in the cohort study from the waterborne outbreak in Transtrand did not deviate from that of the general Swedish population ($P; = 0.746$ and 0.106, respectively). Only 1% responded that they had not been consuming any tap water at home or elsewhere (one baby less than a year and a couple in their 60s).

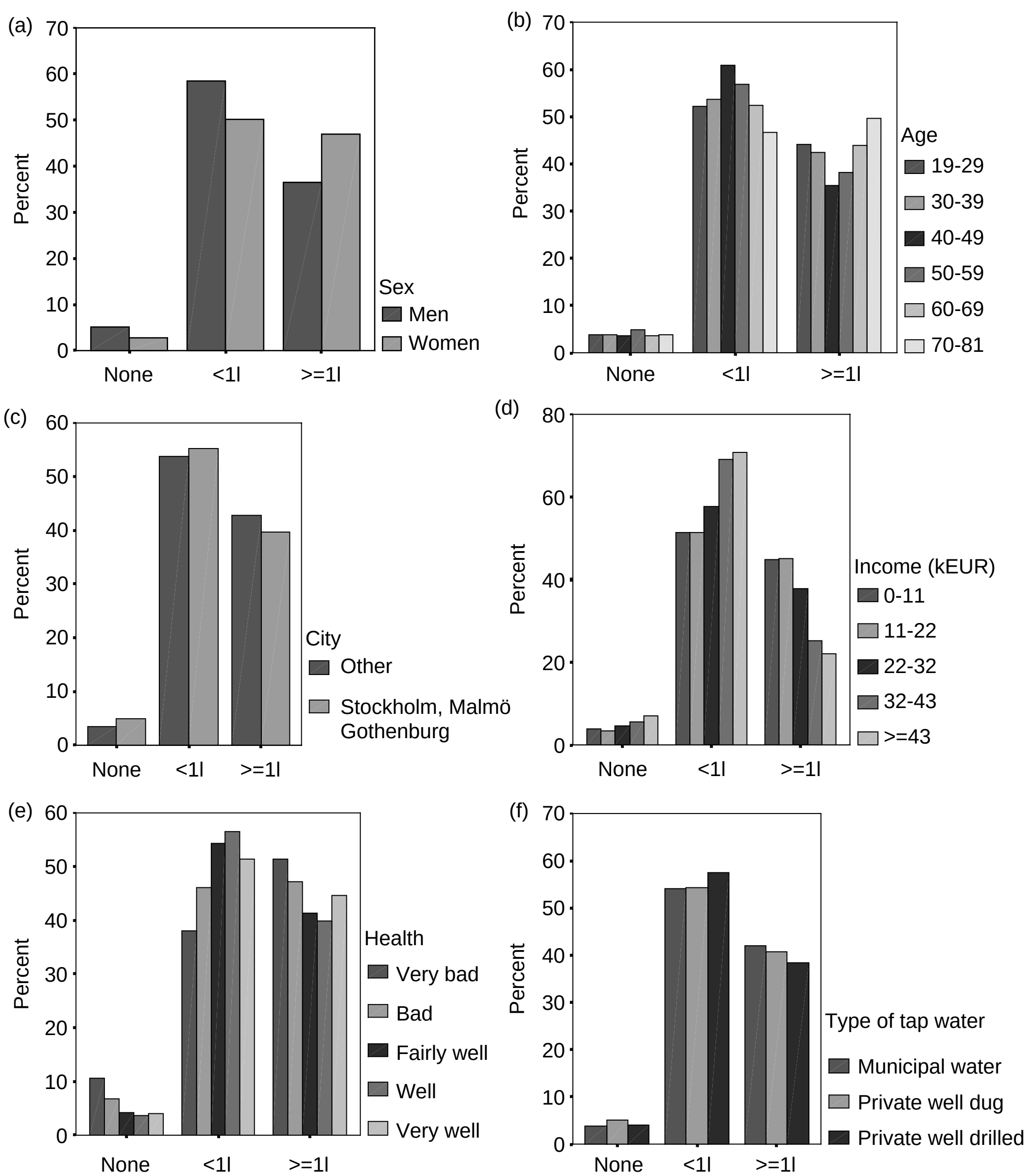

Figure 1 | Daily cold tap water consumption grouped according to a) sex, b) age, c) city, d) income, e) health, and f) type of tap water. Data from the NMHE99. Missing data has been omitted from the figure and generally account for less than 1% of the answers. See Table 1 for numbers in each group.

The reported consumption of cold tap water ranged from one to twelve glasses, i.e. from 0.2 to 2.4 litres. The average water consumption was 0.86 litre with a standard deviation of 0.48 litre. Table 2 shows averages, standard deviations and the 10th, 50th and 90th percentile of the daily cold tap water intake in the Transtrand population, also separated into sex and age groups. The results are in agreement with the NMHE99 survey in that women have a higher consumption than men ($P; = 0.029$). Similar differences between age groups as in the national survey were also observed with 40–49 year olds consuming less than the other groups represented in the NMHE99. The oldest age group had the highest median intake while the 20–29 year olds had the highest mean and maximum intake. The data set also included younger age groups, 0–9 and 10–19 year olds, who consumed the least of all age groups. The youngest, 0–9 years, had the lowest median intake but a high variation (resulting in a higher mean intake than for

Table 2 | Daily consumption of cold tap water in Transtrand

	Average ± Stdv		Percentiles *		
	(l/day)	*n*	10th	50th	90th
Total	0.86 ± 0.48	157	0.40	0.80	1.60
Women	0.95 ± 0.50	79	0.40	0.80	1.80
Men	0.79 ± 0.44	74	0.20	0.80	1.40
Age 0–9	0.64 ± 0.57	16	0.20	0.40	2.00
Age 10–19	0.59 ± 0.19	18	0.40	0.60	0.82
Age 20–29	1.07 ± 0.61	12	0.46	0.90	2.28
Age 30–39	0.97 ± 0.57	21	0.40	0.80	2.00
Age 40–49	0.79 ± 0.48	17	0.20	0.80	1.52
Age 50–59	1.01 ± 0.52	21	0.40	0.80	1.76
Age 60–69	0.89 ± 0.35	26	0.40	0.80	1.46
Age 70 +	0.94 ± 0.36	23	0.48	1.00	1.32

*Estimated using a weighted average.

the 10–19 year olds). A lognormal and a gamma distribution gave equally good fit to the data of the Transtrand population (175 and 173 respectively, with the minimize function that was used in Mathematica on the negative loglikelihood in order to achieve the maximum likelihood), while the fit was poor with a normal distribution (211). Figure 2 shows the cumulative density function of the lognormal distribution (with μ of -0.299 and σ of 0.570) fitted to the Transtrand data (in litres) with maximum likelihood estimation. For comparison, the lognormal distributions for total tap water intake by Roseberry & Burmaster (1992) and for cold tap water intake by Teunis & Havelaar (1999) is included in the graph.

Heated tap water intake in beverages

Water consumption and demography

Out of the 10,957 respondents in the NMHE99 survey 1% answered that they did not make coffee, tea etc. from tap water in their home on a daily basis, 65% stated an intake of less than one litre and 34% one litre or more. In other words, the intake of heated tap water in beverages was less than the amount of tap water consumed directly.

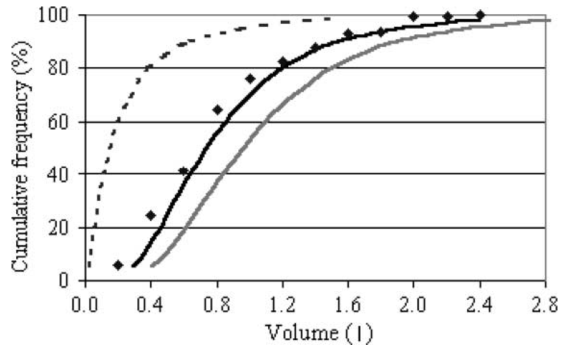

Figure 2 | Cumulative density graph of the cold tap water consumption (in l) in the population in Transtrand (diamonds) and the lognormal distribution fitted to the data (black curve). For comparison, the lognormal distributions for cold tap water intake by Teunis & Havelaar (1999) (dotted curve) and total tap water intake by Roseberry & Burmaster (1992) (grey curve) are included in the graph.

There was no difference either between sexes or age groups in the amount of tap water ingested in beverages ($P; = 0.773$ and 0.180, respectively). Regional differences existed but no trend was observed other than that people living in any of the three largest cities consumed less than the rest of the population ($P < 0.001$). Increasing yearly income was negatively correlated with amounts of tap water consumed in beverages ($P < 0.001$, correlation coefficient -0.057).

People who described their health status as very bad had a higher intake of tap water in beverages than all other groups ($P < 0.05$ for each pair comparison except for comparison with those of “bad” health status where $P; = 0.086$), with 52% consuming more than one litre per day. People with private wells consumed significantly ($P < 0.01$) more tap water in beverages than people with municipal water supply.

Quantitative analysis

The estimates of the daily consumption of heated tap water used for making tea, coffee, instant soups etc. were based on data from the Urban Water study. The proportion of men and women and people in different age groups represented in the Urban Water study did not deviate from that of the Swedish population ($P; = 0.661$ and 0.710, respectively). The consumption ranged from 0.2 to 3.0 litres per day, with a mean and standard deviation of 0.94 and 0.69 litre, respectively. On average 59% of this amount was consumed at home. Men reported a higher consumption of heated tap water than women ($P; = 0.024$). There was no significant difference in intake between age groups or between people in the two cities. Table 3 shows averages, standard deviations and the 10th, 50th and 90th percentile of the daily heated tap water intake. Since this data set is limited in size no further statements are made regarding the separation of the data into sex and age groups.

Bottled water intake

Water consumption and demography

The intake of bottled water in the home among the respondents of the NMHE99 survey was considerably less than that of tap water, 41% consumed less than one litre per day and 56% consumed none. Only 4% reported an intake of more than one litre per day.

There was no difference in bottled water intake between the sexes ($P; = 0.305$) but a significant difference between age groups ($P < 0.001$) where 19–29 year olds consumed the least and 50–59 year olds the most. People in the three largest cities had a significantly higher consumption ($P < 0.001$) than the rest of the country. There were also significant differences between counties ($P < 0.001$).

There was a clear trend of increasing consumption with income, i.e. the more people earned, the more bottled water they consumed ($P < 0.001$, correlation coefficient 0.127). It should be noted that there is a larger percentage of high-income residents in the three largest cities than the rest of the country.

Health status was not a governing factor for bottled water intake ($P; = 0.236$). Respondents connected to a municipal water supply had higher bottled water consumption than those with private wells.

Table 3 | Daily consumption of heated tap water in the Urban Water study

	Average ± Stdv (l/day)	*n*	Percentiles * 10th	50th	90th
Total	0.94 ± 0.69	75	0.23	0.80	2.00
Women	0.77 ± 0.50	39	0.25	0.70	1.35
Men	1.12 ± 0.82	36	0.20	1.00	2.30
Age 20–29	0.78 ± 0.60	10	0.21	0.65	1.95
Age 30–39	0.68 ± 0.47	14	0.18	0.60	1.50
Age 40–49	1.08 ± 0.89	10	0.22	0.65	2.90
Age 50–59	0.77 ± 0.43	18	0.20	0.75	1.10
Age 60–69	1.26 ± 0.82	8	0.35	1.25	–
Age 70 +	1.10 ± 0.94	10	0.30	0.88	3.15

*Estimated using a weighted average.

Quantitative analysis

A large proportion (45%) of the respondents in the limited Urban Water study did not consume any bottled water on a weekly basis. Twenty-five percent consumed less than 0.5 litre, 11% between 0.5 and 1.0 litre, and 13% 1.01 to 2.0 litres. Only 5% consumed ≥2.01 litres per week, or calculated on a daily basis, ≥0.29 litres. The intake was somewhat higher among women than men although not statistically significant ($P; = 0.285$). No significant differences were observed between age groups ($P; = 0.247$), however the youngest age group, 20–29 years, reported the highest intake. There was a significantly higher consumption in the city centre of Gothenburg than in the small town of Surahammar ($P; = 0.004$). Due to differences in the questionnaires regarding time period and number of categories asked for, a direct comparison with the data from the NMHE99 survey is difficult to make. By dividing the categories of the Urban Water study with seven days and fitting a lognormal distribution to the data with maximum likelihood estimation, a quantification of the daily bottled water intake was possible. The distribution was truncated at a maximum of 1.5 litres per day (representing 10.5 litres per week) in order to avoid extremely high values. With this procedure the mean daily intake was 0.06 litre, the median 0.002 litre and the standard deviation 0.19 litre.

DISCUSSION

Several difficulties can be encountered when using data previously collected for other purposes. All data sets in this study were obtained by the use of questionnaires on a single occasion. Some studies suggest that people tend to overestimate their intake in single day measurements compared to measurements over two and three days (Finley *et al.* 1994). Higher water intakes have also been reported from questionnaires compared to diaries (Levallois *et al.* 1998). This could be an effect of recall bias commonly observed when using questionnaires or interviews. Another explanation is that people out of fatigue may not have filled in all intakes in their diary or that they specifically chose a weekend for filling in the diary (Levallois *et al.* 1998). Berg & Viberg (2003) also found differences in reported water intakes between questionnaires and diaries (up to 0.5 l), however it was equally likely to be lower as higher and could therefore have been due to personal variation between days.

The national survey (NMHE99) was specifically designed to obtain a statistically representative sample for the whole country and consisted of a large number of observations, which provided strength to the data set obtained from the survey. One shortcoming for our analysis was that the questions only regarded the water consumption at home. Since the time spent at home may differ depending on sex, age and health status the results may be somewhat biased. Another limitation was the few categories of water consumption that prevented a more quantitative estimation. These problems were addressed by including two additional data sets. Although these were small regarding the number of observations they were statistically representative for the Swedish population regarding age and sex stratification and the results were generally consistent with those of the large survey.

The lognormal distribution fitted to the Transtrand data was similar to that reported by Roseberry & Burmaster (1992), however consistently lower (Figure 2). Besides country-specific differences this effect is most likely explained by the fact that Roseberry & Burmaster used data that included all tap water consumption and not only the direct tap water consumption. Our model would therefore be more suitable for the use in QMRA since only the cold tap water constitutes a risk.

Country specific differences were evident when comparing our probability distribution to that of Teunis & Havelaar (1999) (Figure 2), based on direct tap water consumption in the Netherlands. Compared to the Dutch, Swedes have a much higher direct tap water consumption. It therefore seems to be a need for context dependent probability functions in order to accurately describe risks in QMRA.

When all three water types, cold tap water, heated tap water and bottled water, are put together the daily water consumption in Sweden adds up to 1.86 litres. This figure is in agreement with the total daily water intake reported from other western countries, however the proportion of water intake in the different categories varied (Table 4). Swedes tend to consume very little bottled water compared to other nationalities. The daily bottled water intake was 0.374 l in a Canadian study (Levallois *et al.* 1998) and as much as 1.08 l in springtime in a French study (Gofti-Laroche *et al.* 2001).

The consumption of tap water consumed directly (or plain) also differs markedly. In a study from England and Wales only 17% of the tap water intake was consumed as plain drinking water or used in other cold drinks while 82% was consumed in hot beverages such as tea and coffee (FWR 1996). The corresponding figures for Sweden were 48% and 52%, respectively. The are several reasons why Swedish people may have a high cold tap water intake. The Swedish source waters are generally considered unpolluted. For this reason people do not usually fear chemicals or illness from their drinking water. Due to the cold climate the temperature of the distributed water is low during a large part of the year. Besides making the water more pleasant to drink, the low temperature also results in less biofilm formation in the network and hence less quality changes during distribution (Jonas Långmark, Swedish Institute for Infectious Disease Control, personal communication). Berg & Viberg (2003) report that the respondents show a very positive attitude towards their tap water and generally are of the opinion that it is of very high quality.

Gofti-Laroche *et al.* (2001) present clear seasonal differences in water intake in the French population (Table 4). While the total water intake was 1.87 l in winter, the intake during late spring was 2.23 l. A need for more liquid during warmer periods of the year seems logical; still other studies have found no such differences. Neither of the

Table 4 | Daily water intakes in litres reported from different countries

	Cold tap water	Heated tap water	Total tap water	Bottled water	Total water intake	Ref
Canada	0.386	0.799[a]	1.099	0.374[b]	1.617	Levallois *et al.* 1998
USA[c]	0.506[d]	–	0.927[d]	0.161[b]	1.232	USEPA 2000
France winter[e]	0.77	–	1.58	0.84[f]	1.87	Gofti-Laroche *et al.* 2001
France spring[e]	0.90	–	1.79	1.08[f]	2.23	Gofti-Laroche *et al.* 2001
England and Wales	0.19[g]	0.927[g]	1.138	–	1.561[h]	FWR 1996
The Netherlands	0.153[i]	–	–	–	–	Teunis and Havelaar 1999
Sweden	0.86	0.94[j]	1.80	0.06	1.86	

[a]Also includes tap water added to cold drinks.
[b]The majority is drunken directly.
[c]All individuals.
[d]Water supplied from the municipal water supply.
[e]All values except the cold tap water intake adjusted to the French population, as reported by the authors.
[f]Non-consumers not included.
[g]Calculated from the percentages of the total tap water intake.
[h]Includes all liquids.
[i]Median cold tap water consumption, while other data are mean values.
[j]From Berg and Viberg (2003).

two national surveys in the USA and Canada from the end of the 70's found any strong seasonal variation in tap water consumption (Finley *et al.* 1994; Levallois *et al.* 1998). Finley *et al.* (1994) comment that this "suggests that the distribution of tap water intakes in a population is driven more by variation and personal preference for fluid intake than by the need for additional water cooling." Unfortunately, the data used in the current study does not allow for seasonal comparison.

In the study from England and Wales men consumed a higher total quantity of liquids than women, but women had a higher intake of tap water than men (FWR 1996). In our study women consumed more *cold* tap water than did men. This could imply that women are of a higher risk of becoming ill if the water is contaminated with pathogens. The attack rate in waterborne outbreaks in Sweden is generally very high but men in the age of 20–60 years are affected to a lesser extent based on our experience. In the large *Giardia* outbreak in Norway in 2004 the attack rate was highest among young women (20–29 years) who consumed a high quantity of water (Bergen kommune 2005). The higher cold tap water intake among women could also result in increased risk for pregnant women, although they do not differ in their water intake from other women in a childbearing age (USEPA 2000). Lactating women however drink significantly more water (USEPA 2000; Forhammar *et al.* 1986).

Men on the other hand had a higher consumption of heated tap water than did women in the Urban Water study but not in the NMHE99 survey. The discrepancy between the data could be due to the latter only considering water consumed at home and also including water used for other types of beverages. In the Urban Water study women on average consumed 67% of the heated tap water within the home while the corresponding figure for men was 57%, i.e. men had a higher heated tap water intake outside the home. In a study by Shimokura *et al.* (1998) it was found that full-time employees have more heterogeneous consumption patterns over time, possibly between work days and non-working days, compared to women working part time or less. The authors suggest that employment status could be a stronger determinant of tap water consumption patterns than sex. The difference in occupation status between men and women however could be considered minor in the NMHE99 survey; 58% and 56% of the men and women were employed, respectively. A higher percentage of women (30%) than men (23%) could however be expected to spend a large part of their time at home, e.g. old age pensioners and long-term ill. More women than men also work part-time.

Differences in cold tap water intake existed between age groups, and people older than 70 years had the highest consumption. The elderly constitute a sensitive group since they may be less able to build up an effective defence against microbial or chemical contaminants because of a weakened immune system or pre-existing disease. Case-fatality rates for some of the enteric pathogens known to be transmissible via water is ten to hundred times greater in the elderly than the general population (Gerba *et al.* 1996). Infants and children are also sensitive to microbial and chemical contaminants because their defence mechanisms may not be fully developed. Although the consumption was lowest among the youngest age groups (0–9 and 10–19) children have higher ingestion in relation to their body weight, which can make them more sensitive to contaminants. This ratio is approximately three to four times higher for babies younger than one year old than that of the general population (USEPA 2000). A study by Pettersson & Rasmussen (1999) confirms that Swedish infants aged 9 to 21 months drink as much tap water (0.62 l per day) as older children (Table 2).

No significant statistical differences were found between age groups in the heated tap water intake in this study. The age group 60–69 years reported the highest heated tap water intake. Levallois *et al.* (1998) comment that older people generally consume more water via hot beverages and soup. Some authors report a trend of increasing total tap water consumption with age up to 55–60 years and thereafter a slight decrease (FWR 1996; Gofti-Laroche *et al.* 2001), while others present increasing consumption in age groups also above 65 years (Roseberry & Burmaster 1992).

People who regarded themselves to be of very bad health compared to people of the same age had the highest intake of both cold tap water and tap water added to hot beverages within their home. One reason for this could be that they spend a lot of time in their residence. When looking at employment status, the long-term ill and people on a disability pension stated the worst health (data not shown). High water intake in these groups could arise from certain types of medication or disease conditions that causes thirst, e.g. the use of some anti-depressant drugs or diabetes (Guyton 1991).

The group of people of very bad health also had the highest proportion of persons not consuming any cold tap water. In some countries, sensitive groups such as the immuno-compromised are advised to consider not drinking tap water without prior boiling or treatment in filtering devices due to potential contamination with pathogens, especially *Cryptosporidium* (CDC 2003; Melita Stevens, Melbourne water, Australia, personal communication). Aragón *et al.* (2003) found that the proportion of cases of cryptosporidiosis in AIDS patients contributable to tap water consumption could be as high as 85%. No water restrictions of this kind however exist in Sweden.

The analysis also showed that the further north a person was living in Sweden, the higher their intake of cold tap water. The availability of alternative beverages could perhaps explain the large difference in intake of cold tap water between people living in the three largest cities and the rest of the country, with the former consuming significantly less cold tap water than the latter. Eleven out of twelve cities with a population greater than 100 000 residents are located in the southern part of the country. Another reason could be differences in water sources. Large cities in Sweden mainly use surface water as the raw water source, while small municipalities normally extract water from several groundwater wells. It is possible that drinking water produced from groundwater tastes better than that from surface water due to less compounds that can cause odour and taste problems, such as those originating from algae.

Regional differences have also been observed in other studies. A higher intake of tap water was reported in the northern areas of England and Wales compared to the midlands (FWR 1996). Levallois *et al.* (1998) found that residents of rural areas tended to consume more natural water (direct water) compared to residents of urban areas, however the results were not statistically significant.

According to Berg & Viberg (2003) the consumption of bottled water is mainly linked to accessibility and trends. The accessibility aspect could explain why the bottled water consumption is higher in the large cities than the rest of the country. Berg & Viberg also claim that city people more readily adopt trends and bottled water has for several years been associated with a healthy lifestyle through commercials. The reason why people with private wells had a lower consumption of bottled water than those with municipal water could also be attributable to accessibility, since private wells are most common in remote areas. In the report from the Foundation for Water Research, UK, (1996) it is proposed that bottled water consumption increases with increasing social class. Income is one of the measures of social class and in our study the bottled water consumption increased with income. Whether this is in fact a result of the price of bottled water in Sweden, approximately a thousand times higher than the price of tap water, or again to accessibility in that a higher percentage of high-income residents dwell in the three largest cities compared to the rest of the country, is difficult to distinguish.

It does not appear that bottled water has replaced tap water as a beverage, rather that bottled water has substituted other commercially produced beverages. According to statistics from the Swedish Brewery's Association (2004) the consumption of bottled water has almost doubled during the last ten years, from 10.8 l per person per year in 1993 to 20.4 l in 2003 (which actually makes 0.06 l per day, the same as in this study). During the same time period, the consumption of low alcohol beer, which is often served with meals, has decreased from 11.6 to 5.4 l per capita and year. In England and Wales both the tap water and bottled water consumption increased from 1978 to 1995 while the total liquid consumption remained the same (FWR 1996).

Sweden has a long history of surveillance of waterborne disease outbreaks (Andersson & Bohan 2001). The high detection of outbreaks is mainly attributable to an efficient diagnostic and reporting system rather than highly contaminated water sources or bad management of drinking water systems. However, since the chlorine dosing in surface water systems is low and groundwater systems are rarely chlorinated the systems are sensitive to contamination. The maximum chlorine residual at the consumers tap in Sweden is 0.4 mg/l. Surface water systems have been responsible for the largest waterborne outbreaks; nevertheless most outbreaks occur in groundwater systems where the most common cause is contamination of the water source through wastewater infiltration (Andersson & Bohan 2001).

A crack in a sewage pipe near the groundwater well was also the cause of the waterborne outbreak in Transtrand, Dalarna. In the outbreak there was a clear trend of increasing probability of illness with increasing tap water consumption among school children (Carrique-Mas *et al.* 2003) that is, a clear dose-response relationship. A clear dose-response relationship has also been reported from the large waterborne outbreak with *Giardia* in Norway in the autumn of 2004 (Bergen kommune 2005). Knowledge of water consumption in the population, and especially of the variability in consumption, can be used in microbial risk assessments for establishing which risk prevention measures are necessary to implement. The lognormal distribution fitted to the data on direct (cold) tap water consumption represented the total population and had an upper 95-percentile (from a randomised sample from the distribution, data not shown) of 2.2 litres. This figure is in agreement with the standard quantity of 2 litres currently adopted by the USEPA and WHO, although the latter is supposed to represent the total water intake. Since subsets of the population belonging to groups sensitive to infections in general were also shown to have a high tap water intake, there may be a need for more stringent measures in order to protect these groups from potential contaminants in water.

CONCLUSIONS

The current compilation of drinking water consumption patterns addressed several important issues for the ongoing development of reliable quantitative microbial risk assessment (QMRA) models. The probability distribution for the cold tap water intake developed from the Swedish data was somewhat lower than published distributions for total tap water consumption (Roseberry & Burmaster 1992) but much higher than the Dutch distribution for cold water consumption (Teunis & Havelaar 1999). Although the proportion of water consumed from different sources varies between countries, other results could be more generally applicable. Women for example, were shown to consume more cold water than men, while an opposite trend was observed for hot water beverages. Furthermore, this study demonstrated that already sensitive sub-populations, such as the elderly, sick and young had a higher water intake than other groups (in the case of the latter, in relation to their body weight). There is therefore a need for the development of specific intake distributions for sensitive groups. Meanwhile, the standard quantity for drinking water intake of 2 litres per person per day could still be used as a conservative estimate in risk assessments since it represented the intake of the upper percentiles of the population.

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